Modeling CNS for the Virtual Air Space Technologies Toolbox

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Virtual Airspace Modeling and Simulation (VAMS) Project

Is an NASA initiative to develop modeling and simulation capabilities that facilitate examination of operational concepts that presume to provide a significant increase in the capacity of the National Airspace System, while maintaining safety and affordability.

VAMS Objectives:

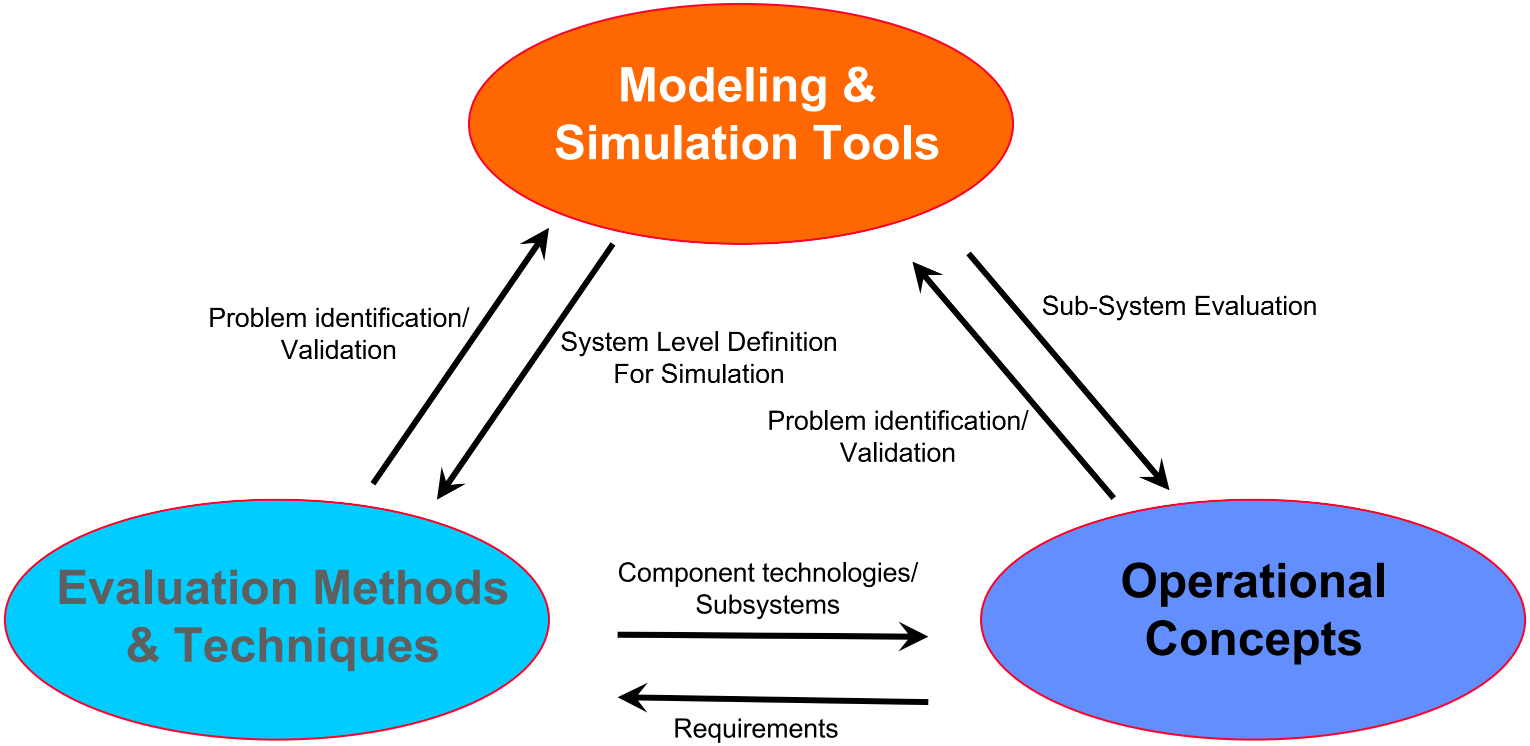
To define potential operational concepts;

To generate supporting technology roadmaps;

To establish the capability to assess these concepts.

Virtual Air Space Technologies (VAST):

A project sub-element of VAMS intended to develop capabilities to simulate operations within the National Airspace System (NAS) to levels of fidelity sufficient for the research being performed, while maintaining safety and affordability.



CNS Modeling Tool

- NASA’s Glenn Research Center tasked with the development of Communications, Navigation and Surveillance (CNS) tools to support VAST modeling efforts.

- CNS tools will characterize the probabilistic and deterministic effects of “imperfect” CNS.

- The sources of imperfection in CNS modeling are unique to each communication, navigation or surveillance category, and are manifest in errors associated with the measurement accuracy of these devices.

- “Imperfect” communications refers to messages that are delayed in reaching the pilot or controller. The delay could be caused by media error, congestion on the network, or multiple messages colliding.

CNS Modeling Tool (cont.)

- "Imperfect" navigation refers to the accuracy of an aircraft's location as determined by its type of navigation system. The type of aircraft navigation system (e.g., GPS or VOR/DME) determines the degree of accuracy achieved in determining an aircraft's location.

- "Imperfect" surveillance refers to the accuracy of an aircraft's location as presented to a controller or another aircraft. The level of accuracy is dependent upon the type of surveillance device employed.

- Unique aspect of the VAST modeling environment is the employment of the Department of Defense's High-Level Architecture (HLA) interface definitions. These definitions are the VAST project's chosen method for the exchange of data between simulations or models in the VAST Tool Box.

What is the High Level Architecture?

The **High Level Architecture** is comprised of three elements:

- An **Interface Specification** which describes the way compliant simulations interact during operation
- An **Object Model Template (OMT) Specification** which specifies the form in which simulation elements are described
- A set of **HLA Rules** for Federates and Federations which define relationships among federating compliant simulations

HLA's approach promotes:

- <u>INTEROPERABILITY</u> among federating simulations, and across functional M&S communities, and
- <u>REUSE</u> of simulation components across federations, functional M&S communities, and runtime infrastructures.

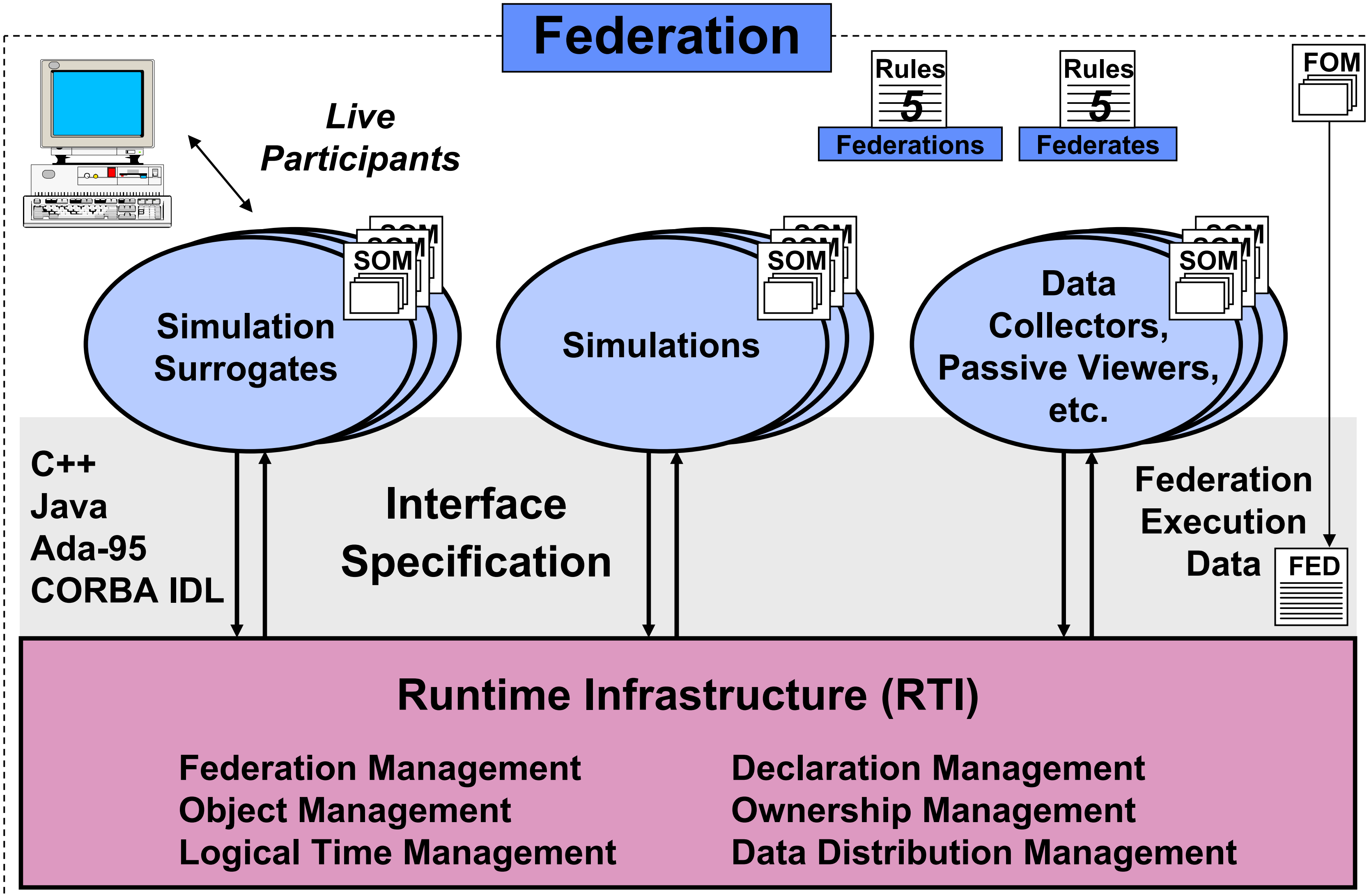
HLA Terminology

- **Federation:** a named set of federate applications and a common federation object model that are used as a whole to achieve some specific objective.
- **Federation Execution:** The actual operation, over time, of a set joined federates that are interconnected by a Runtime Infrastructure (RTI).
- **Federate:** a member of a federation; one application
  - Could represent one platform, like a cockpit simulator
  - Could represent an aggregate, like an entire national simulation of air traffic flow
  - Could represent a support application like a stealth viewer or a data collector

HLA Terminology (continued)

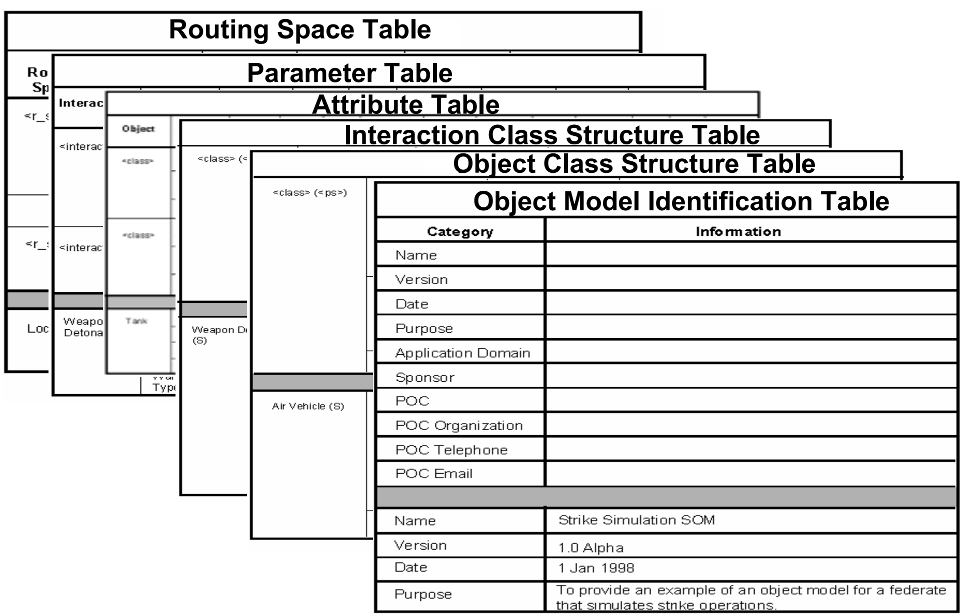
- **Object:** An entity in the domain being simulated by a federation that is of interest to more than one federate and is handled by the RTI.
- **Interaction:** An explicit action taken by a federate that may have some effect or impact on another federate within a federation execution.
- **Attribute:** A named characteristic of an object class or object instance.
- **Parameter:** A named characteristic of an interaction.

Functional View of the High Level Architecture



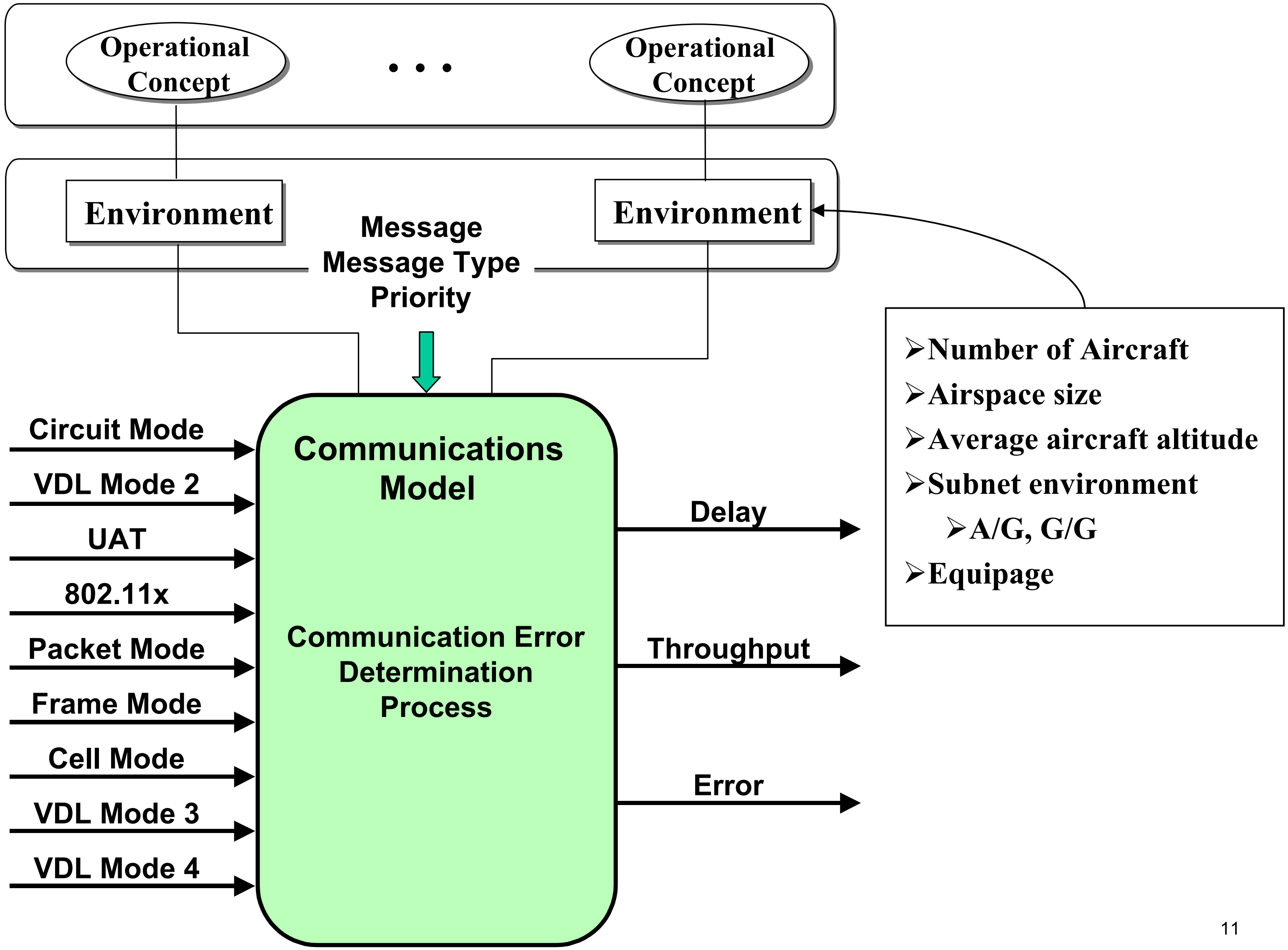
HLA Object Models and OMT

- **Federation Object Model (FOM)**
  - **A specification defining the information exchanged at runtime to achieve a given set of federation objectives.**
- **Simulation Object Model (SOM)**
  - **A specification of the types of information that an individual federate could provide to HLA federations as well as the information that an individual federate can receive from other federates in HLA federations.**

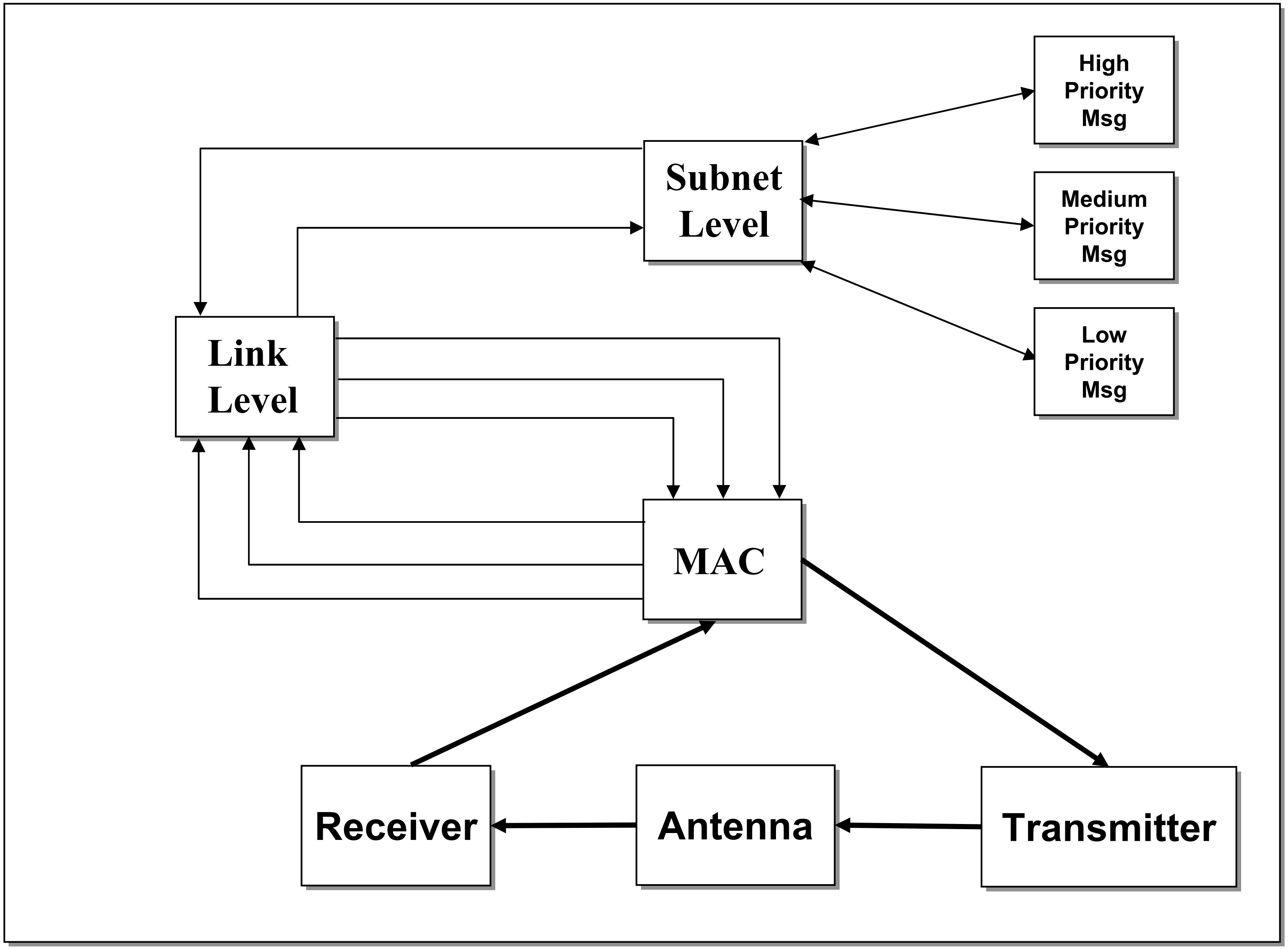


- **Object Model Template (OMT)**
  - **Provides a common framework for HLA object model documentation**
  - **Fosters interoperability and reuse of simulations via the specification of a common representational framework**

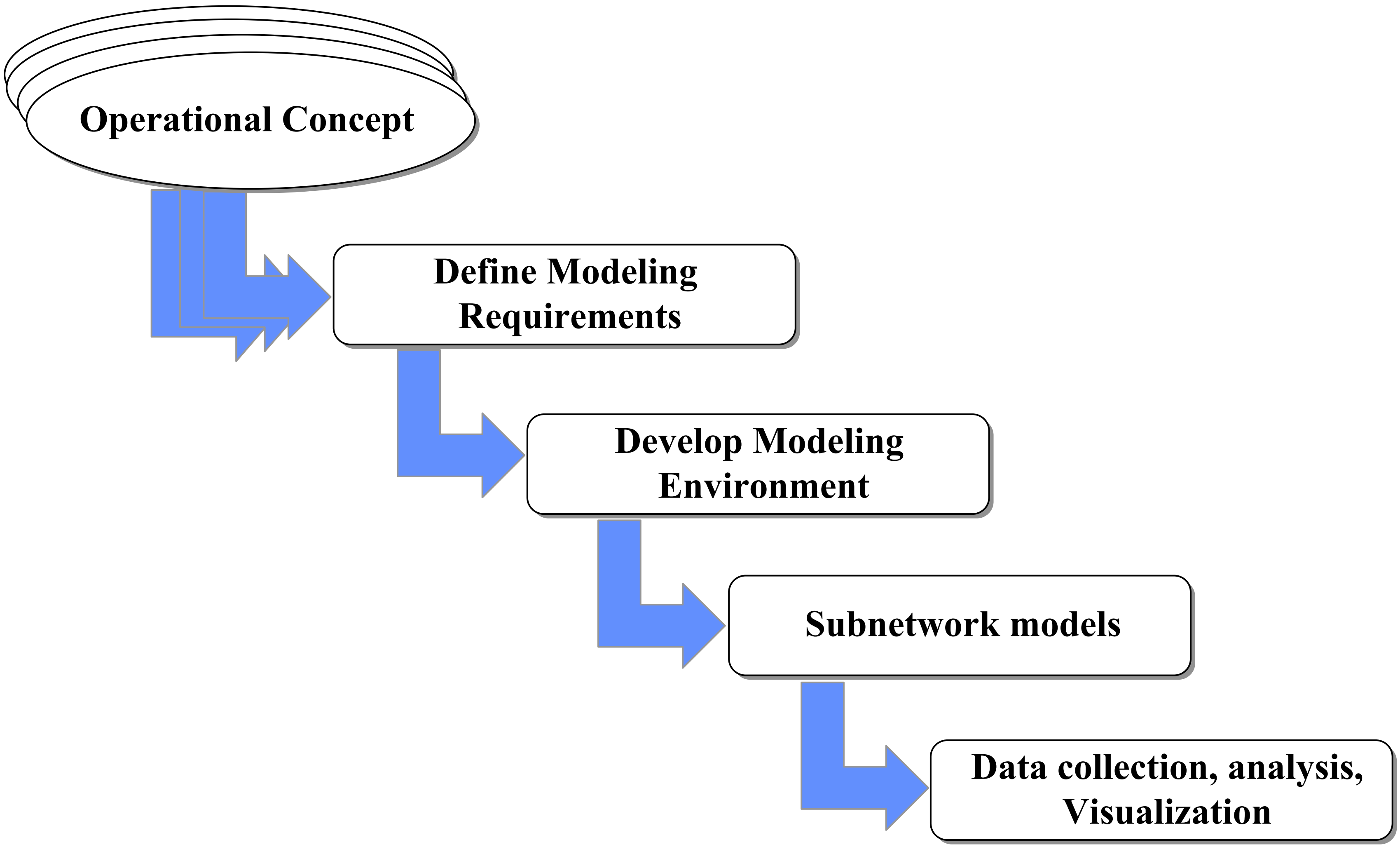
Communications Conceptual Model



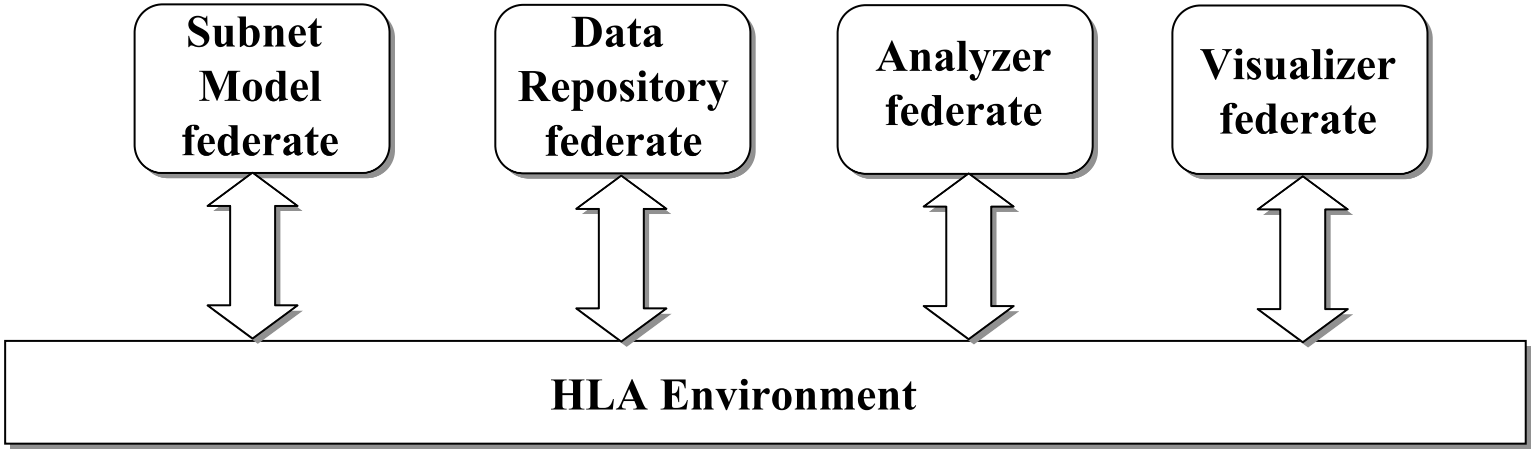
Communications Subnet Model



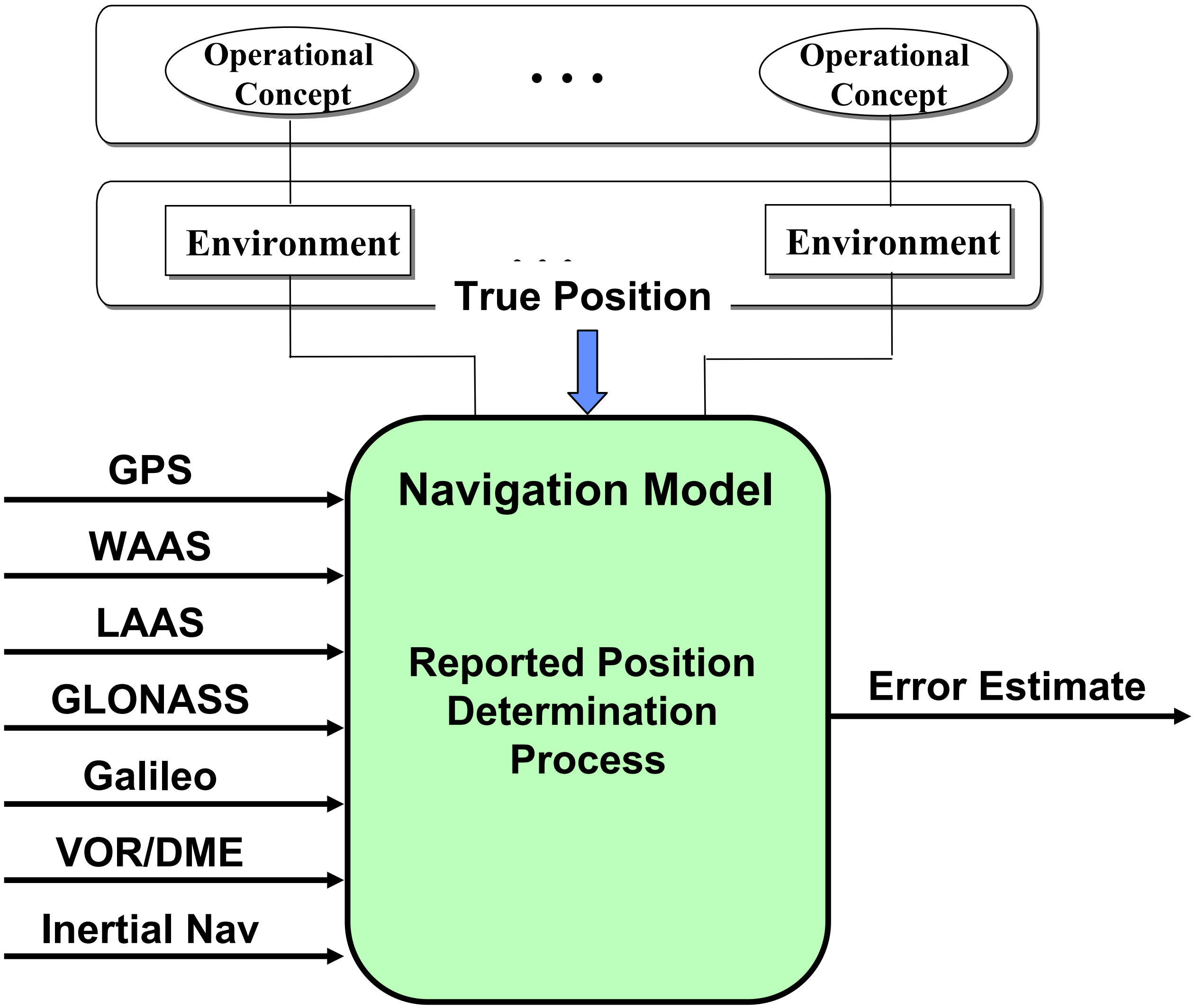
Communications Modeling Methodology



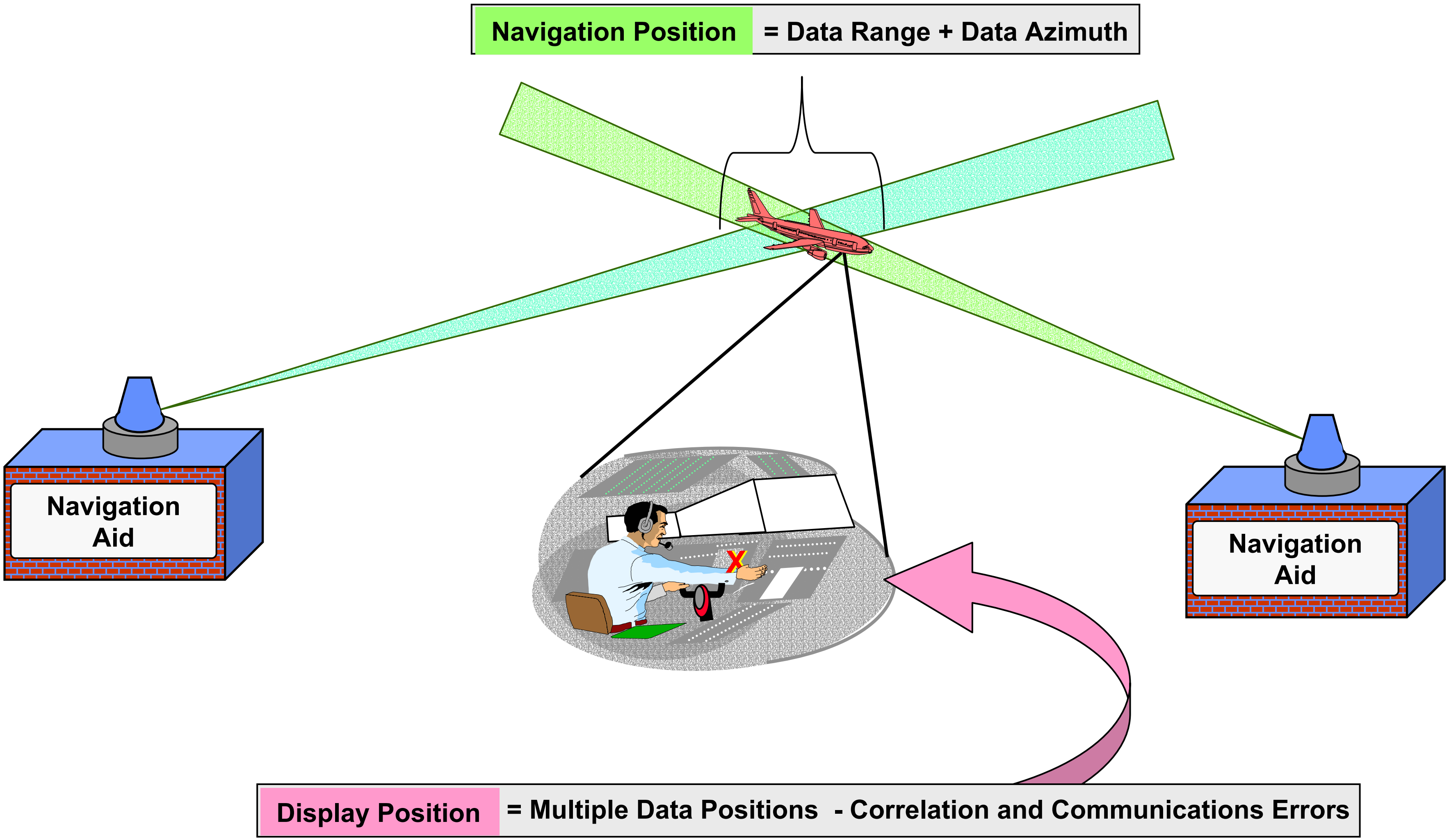
Comm Modeling in HLA Environment



Navigation Model

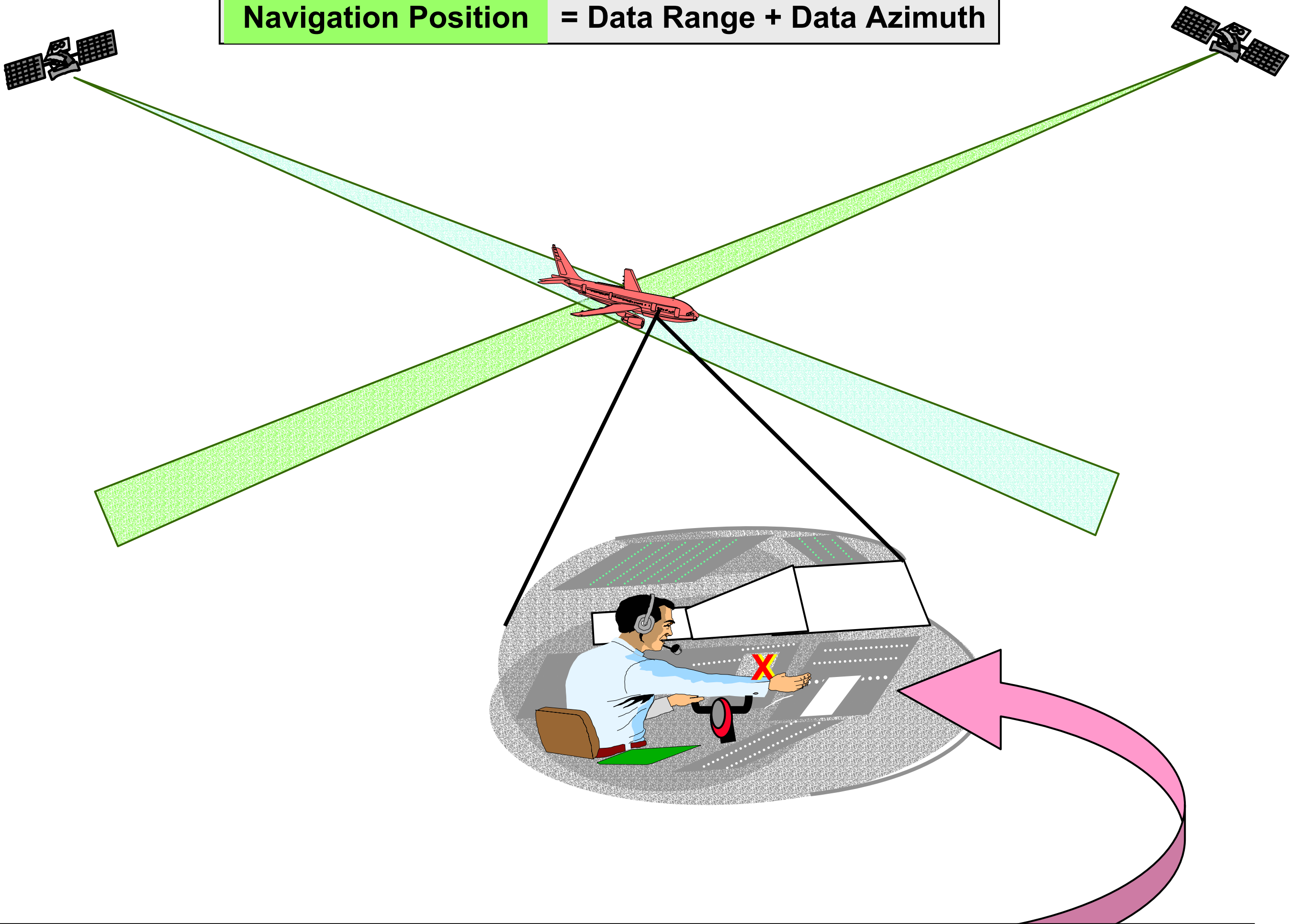


Navigation Model - Ground-Based



Navigation Model - Space-Based

Navigation Position = Data Range + Data Azimuth



Display Position = Multiple Data Positions - Correlation and Communications Errors

Navigation Error Sources

- Ground Facility Errors
  - Azimuth/bearing
  - Range
- GPS/WAAS/LAAS
  - Position
  - Correlation (GPS/WAAS or GPS/LAAS)
  - LAAS Terrain Masking
- Aircraft Instrumentation
  - Calibration/Drift
  - Navigation input processor correlation (False reporting)

Navigation Error Characteristics

- Satellite Navigation Accuracy (Pilot Perspective)
  - Global Positioning System*
    - NAVSTAR GPS: ≤ 6.3 meters
    - GPS/Wide Area Augmentation System: ≤ 7 meters
    - GPS/Local Area Augmentation System: ≤ 0.36 meters
    - Maritime Differential GPS (USCG): ≤ 3 meters
    - High Precision Differential GPS (NASA): ≤ 20 centimeters (~ 8 inches)
    - Carrier Phase Differential GPS: ≤ 1 centimeter (0.4 inches)
  - Global Navigation Satellite System (GLONASS)*
    - Uncorrected: ≤ 20 meters
    - With Differential Receiver: ≤ 1 meter
  - Galileo (2008)*
    - Guaranteed: ≤ 4 meter

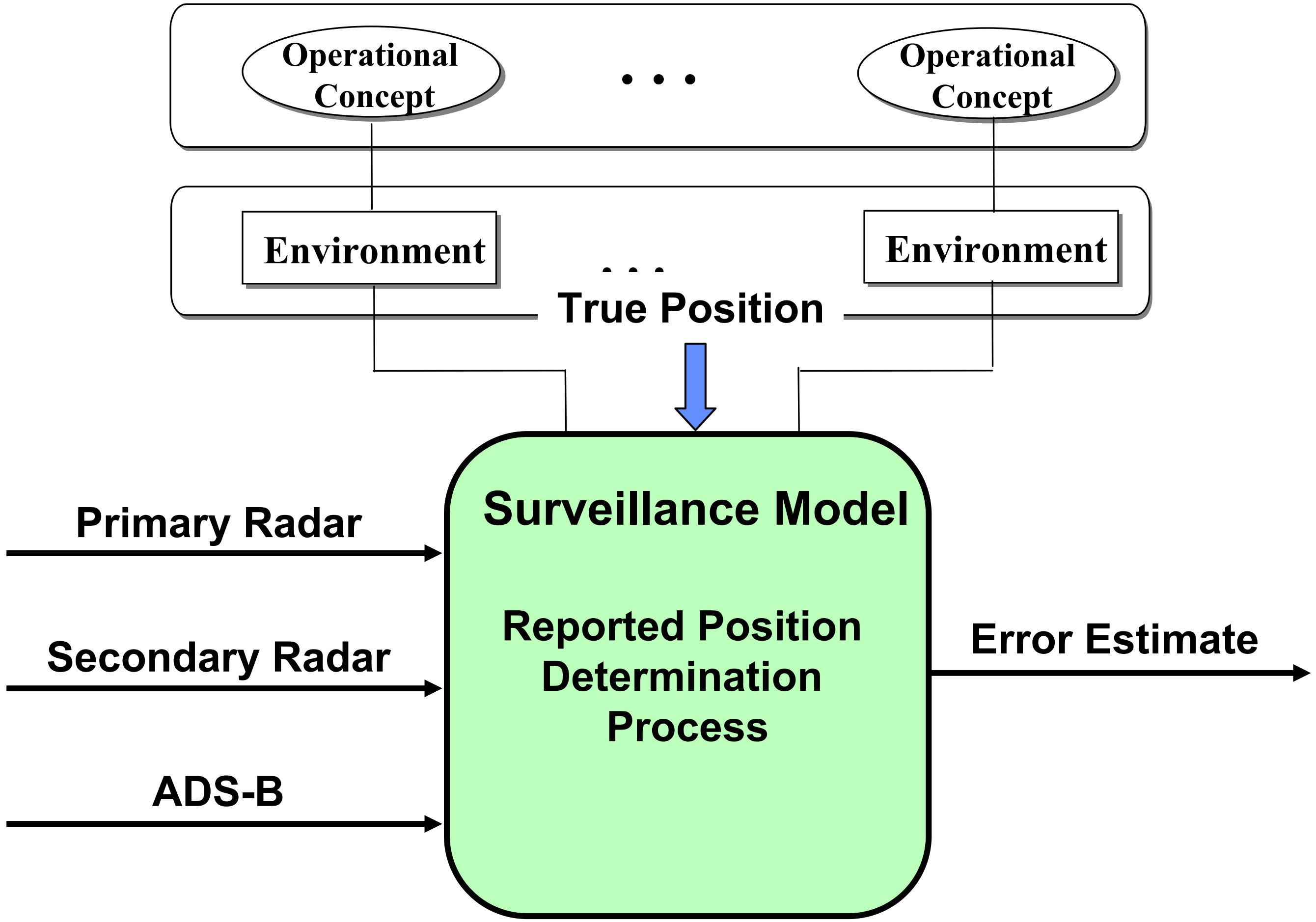
* Source: Benson, Eric, *Global Navigation Satellite Systems*, Automated Guidance Group, University of Illinois at Urbana - Champaign, 2001

Navigation Error Characteristics

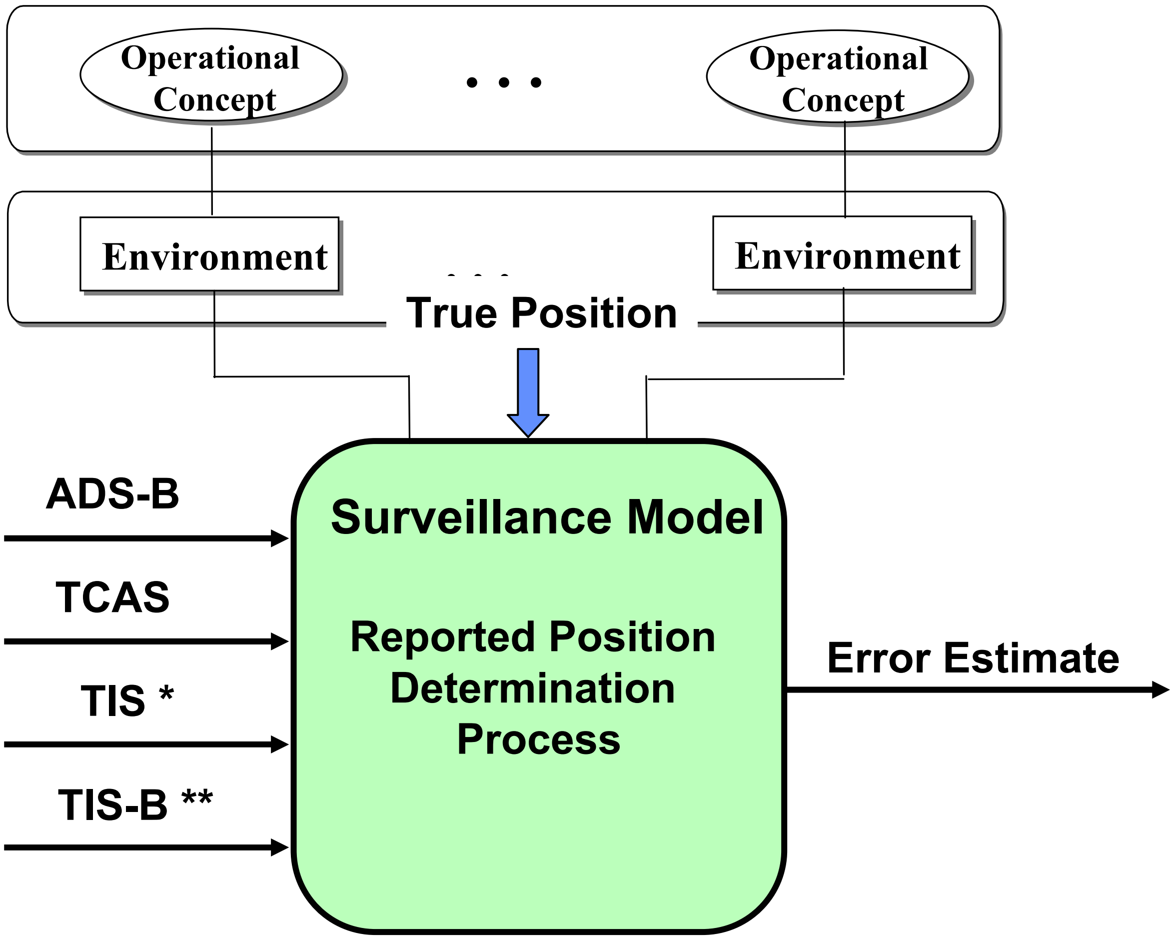
- Inertial Navigation System
  - Self-Contained On-board System*
    - Gyro Error = 0.01 degrees/hour drift
    - Accelerometer Error = 50 μg (millionths of a g force)
- Ground-Based Navigation (VOR, DME)
  - Ground Station Azimuth Error: ≤ 2 degrees
    - Terrain Bending/Distortion
  - DME (slant range errors) depends upon range from the NAVAID
    - Slant range distance - Ground distance = 2 nm if aircraft is at 36,000 feet and the DME reading is 10 nm

* Source: Wang, Jinling, *Inertial Navigation System (INS) and Dead Reckoning (DR)*, School of Surveying and Spatial Information Systems, University of New South Wales, Australia, October 18, 2001

Surveillance Model - Controller



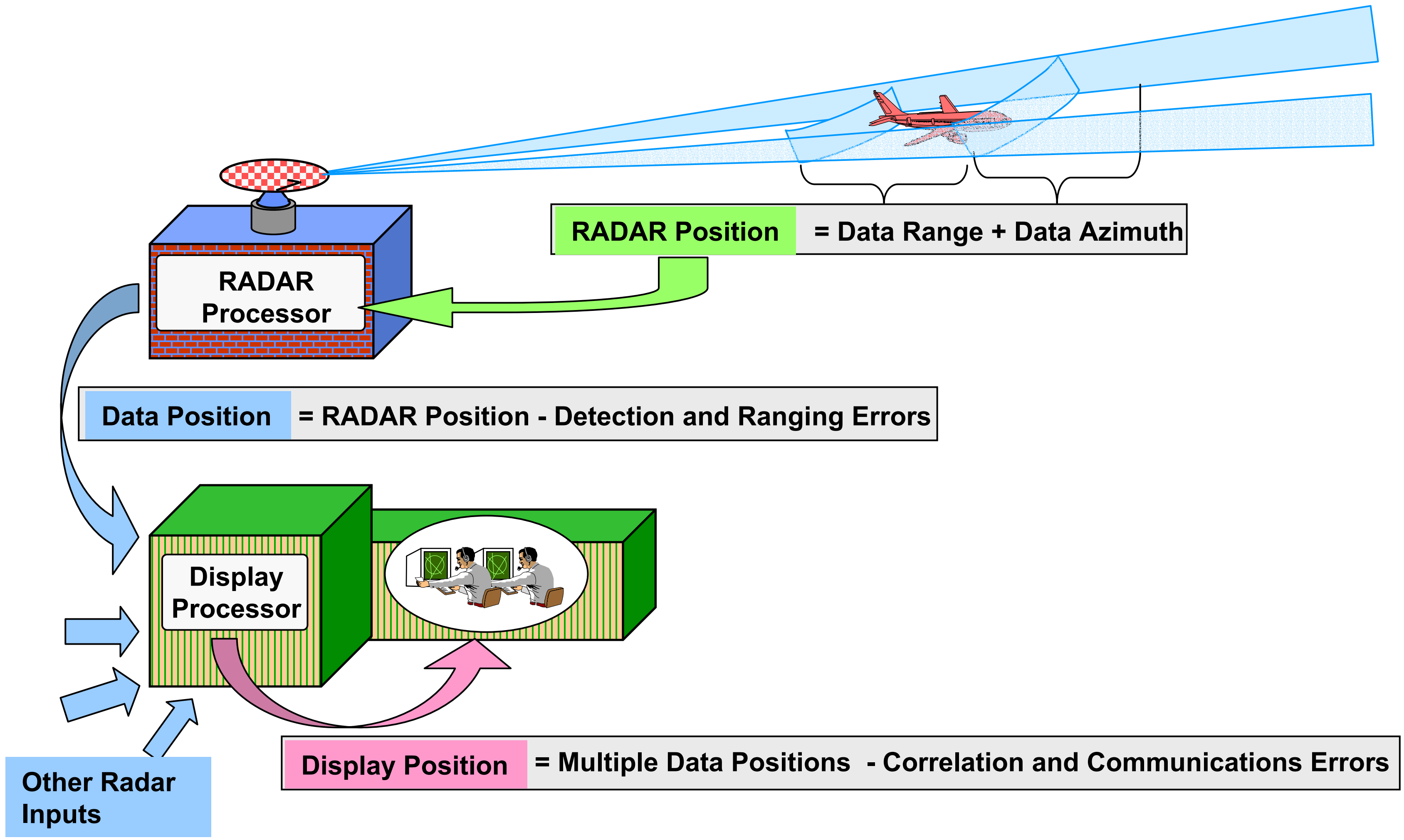
Surveillance Model - Pilot Perspective



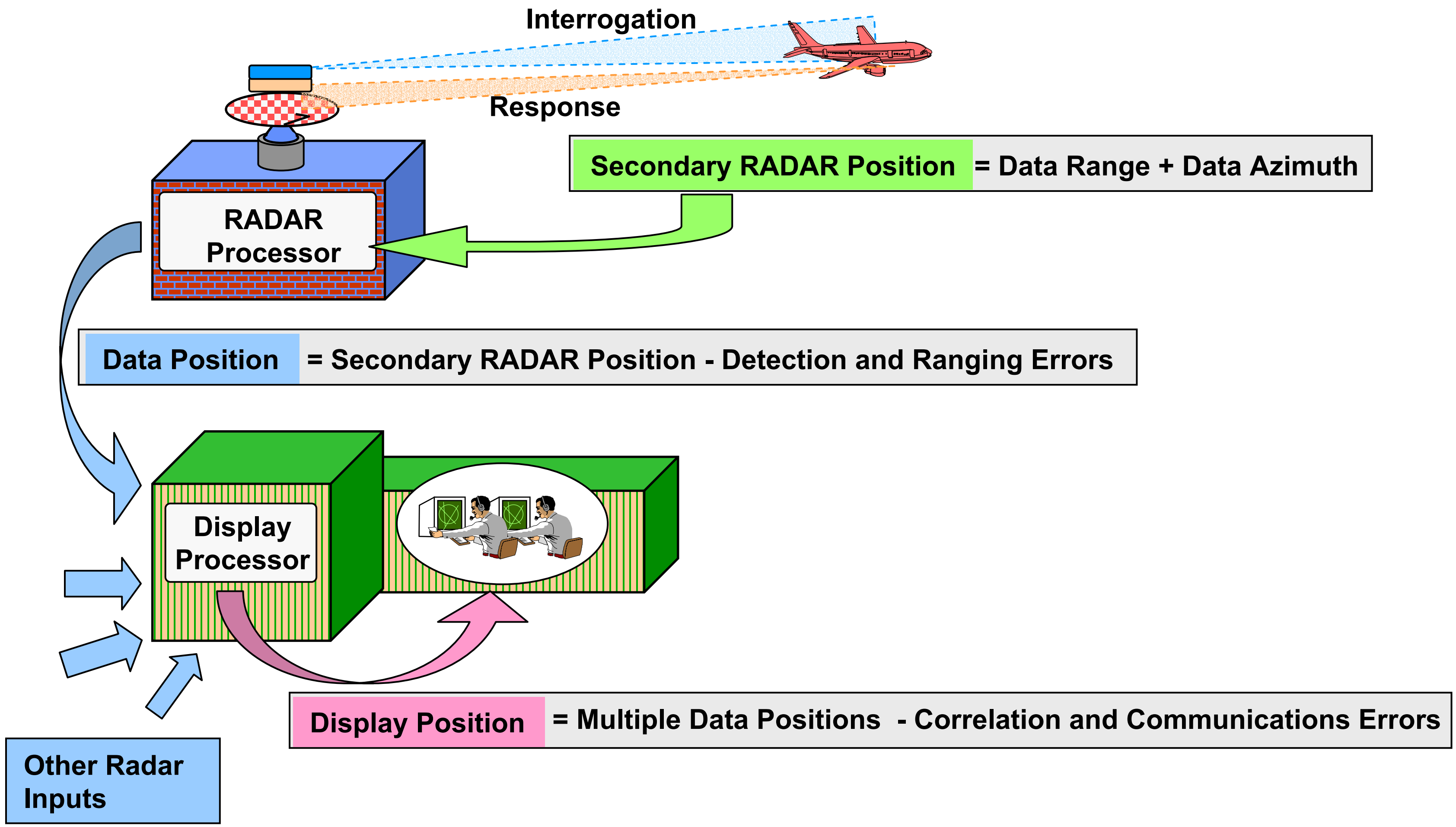
* Contains errors associated with primary and secondary radars

** Contains errors associated with primary and secondary radars plus ADS-B

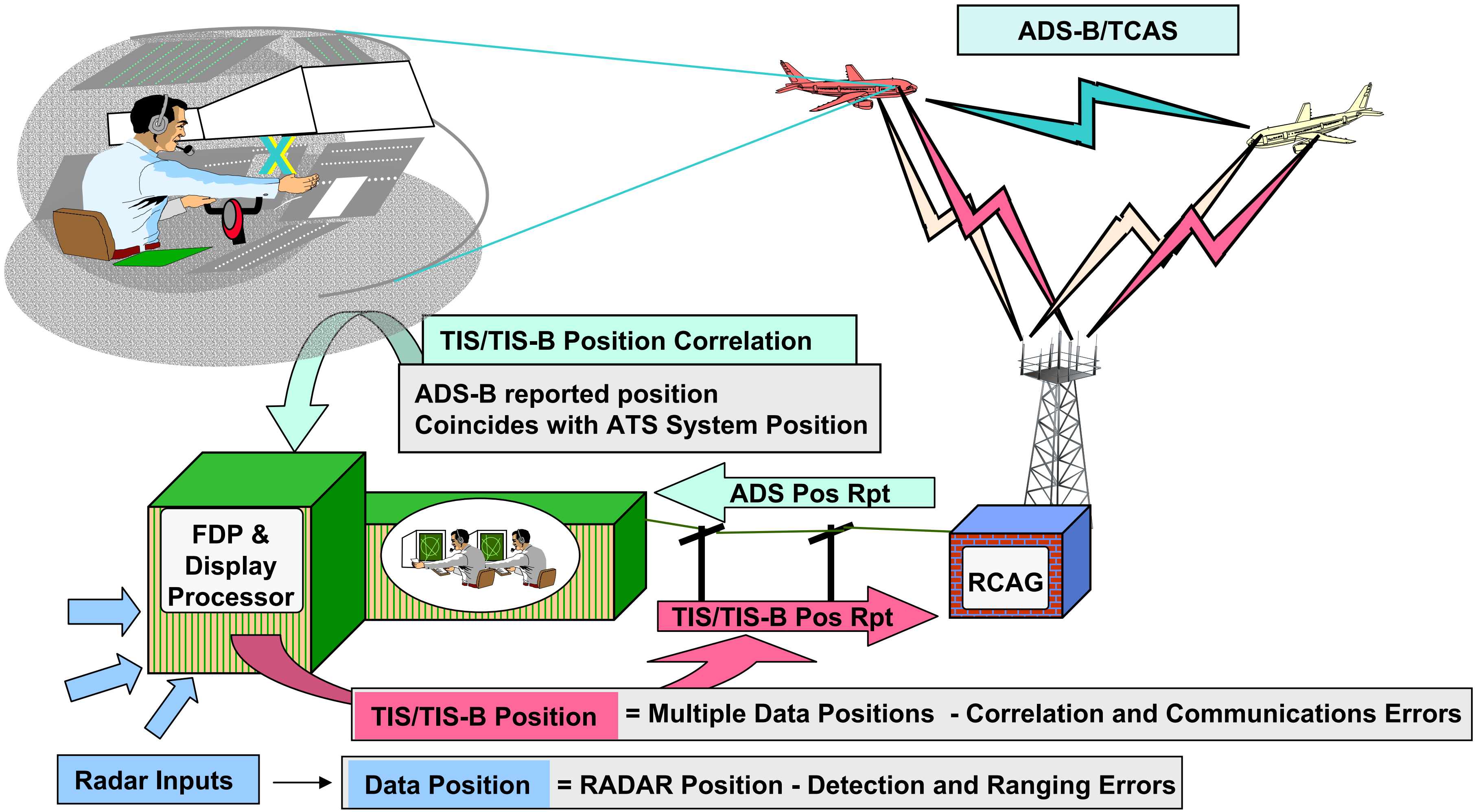
Ground Surveillance - Primary Radar



Ground Surveillance - Secondary Radar



Airborne Surveillance Model



Surveillance Error Sources

- Radar Alignment
  - Azimuth accuracy
  - Range accuracy
- Radar Signal Processor
  - Position
  - Trajectory
  - Ducting
- Flight Data Processor/Display Processor
  - Data recording resolution
  - Multiple source correlation position errors

Surveillance Error Characteristics

- Surveillance Radar (Primary and Secondary)
  - Range Precision
    - En route: 1/4 nm
    - Terminal: 1/64 nm
  - Correlation (two or more radars): Improves accuracy
  - Smoothing for En Route Radar (5 rpm antenna)
    - Aircraft at 200 KTAS, turning with a 20º angle of bank: < 0.6 nm
    - Aircraft (e.g., B737 to B777) at 500 KTAS, turning with a 20º angle of bank: < 1 nm
- Position Uncertainty due to Display Refresh Rate
  - Max allowed refresh rate is 7 sec.
  - Aircraft at 500 KTAS travels 1 nm in 7 sec.
- Calibration

Surveillance Error Characteristics

- ADS-B (Controller Perspective)
  - Accuracy of Reported Position (Sources: DO-242A & DO-282)
    - Navigation Accuracy Category for Position: 3 m - 10 nm
    - Navigation Accuracy Category for Velocity: 0.3 - 10 m/s
    - GPS Antenna Location vs Center of Aircraft: < 20 m
  - Location Precision in Message: ~ 3 m
  - Position Uncertainty due to Message Collision (Missed Report)
    - Report cycle ranges between 1 and 12 sec updates.
    - With 12 sec updates aircraft at 500 KTAS travel 1.7 nm between reports.
  - Correlation with Other Sources: Improves Accuracy
  - Calibration of Display

Surveillance Error Characteristics

- ADS-B (Pilot Perspective)
  - Accuracy of Reported Position (Sources: DO-242A & DO-282)
    - Navigation Accuracy Category for Position: 3 m - 10 nm
    - Navigation Accuracy Category for Velocity: 0.3 - 10 m/s
    - GPS Antenna Location vs Center of Aircraft: < 30 m
  - Location Precision in Message: ~ 3 m
  - Position Uncertainty due to Message Collision (Missed Report)
    - Report cycle ranges between 1 and 12 sec updates.
    - With 12 sec updates aircraft at 500 KTAS travels 1.7 nm between reports.
  - Calibration of Display (CDTI)

Surveillance Error Characteristics

- TIS (Pilot Perspective)
  - Accuracy of Position Data from Ground Surveillance Source
    - Primary & Secondary Radar
  - Precision of Message (Source: DO-239)
    - 1/8 nm horizontal position
    - 100 feet altitude
  - Delay: ≤ 6 seconds
  - Calibration of Display (CDTI)

Surveillance Error Characteristics

- TIS-B (Pilot Perspective)
  - Accuracy of Position Data from Ground Surveillance Source
    - Primary & Secondary Radar
    - ADS-B
  - Location Precision in Message (Source: DO-282) : ~ 3 m
  - Calibration of Display (CDTI)

Summary

✈Modeling the effectiveness of the VAMS operational concepts is dependent upon the fidelity of the modeled CNS systems.

✈Improving the modeling fidelity by simulating the real-world "imperfections" associated with CNS systems provides the capabilities needed for accurate and realistic assessments of the operational concepts.

✈Implementing HLA as an infrastructure mechanism that allows the CNS models to be integrated with the VAMS fast-time and real-time simulations.

Acknowledgements

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